Claims

1. A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:

    forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, zero or more layers of other materials separating layers A and B, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B;

    observing the overlaid diffraction gratings using an optical instrument capable of measuring any one or more of transmission, reflectance, or ellipsometric parameters as a function of any one or more of wavelength, polar angle of incidence, azimuthal angle of incidence, or polarization of the illumination and detection; and

    determining the offset between the gratings from the measurements from the optical instrument using an optical model, wherein the optical model accounts for the diffraction of the electromagnetic waves by the gratings and the interaction of the gratings with each other's diffracted field.

2. The method of claim 1 wherein any layers between the grating in layer A and the grating in layer B are at least partially transparent at the wavelength range of the optical instrument.

3. The method of claim 1 wherein at least one layer between the grating in layer A and the grating in layer B is opaque in the wavelength range of the optical instrument, and the presence of the grating in layer A causes a grating-shaped topography on the surface of the opaque layer.

4. The method of claim 1 wherein the optical model represents the electromagnetic field in the gratings and in the layers between the gratings as a sum of more than one diffracted orders.

5. The method of claim 1 wherein offset is determined by:

calculating, according to a model of a wafer sample, the optical response of the sample with the said two overlapping gratings, the model of the sample taking into account parameters of the sample including any of the overlay misalignment of layers A and B, the profiles of the grating structures, and asymmetries caused in the grating structures by manufacturing processes;

changing the parameters of the sample model to minimize the difference between the calculated and measured optical responses; and

repeating the previous two steps until the difference between the calculated and measured optical responses is sufficiently small or cannot be significantly decreased by further iterations.

6. The method of claim 5 wherein at least a portion of the calculation is done at the measurement time.

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7.   The method of claim 5 wherein at least a portion of the calculated optical response is retrieved from a pre-computed database.

8.   The method of claim 5 wherein the calculation involves interpolating the optical response from pre-computed entries in a database.

9.   The method of claim 1 wherein the first and second diffraction gratings have different pitches.

10.   The method of claim 1 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

11.   A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:

        forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a first patterned layer and a second diffraction grating is built into a second patterned layer, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B, and at least one of the first or second gratings having a repeating pattern consisting of at least two structures of substantially different lateral dimensions;

        measuring the optical characteristics of the overlaid diffraction gratings using an optical instrument with a spot size covering at least two repeats; and determining the offset between the gratings from the measured optical characteristics.

12. A method of determining a degree of registration between an upper layer and a lower layer formed on a substrate, each of said layers including a periodic structure formed thereon and arranged to at least partially overlap, said method comprising the steps of:

illuminating the layers with a probe beam of radiation;

monitoring the zeroth order light diffracted from the layers;

generating a parameterized model representing the geometry and registration of parameters of the model; and

comparing the predicted optical response with the monitored zeroth order light to determine the registration of the structures.

13. A method as recited in claim 12 wherein said predicting step is at least partially carried out in advance for a number of different parameters and wherein the corresponding responses are stored in a database for later comparison with the monitored response.

14. A method as recited in claim 12 wherein the predicting and comparing steps are repeated while changing the parameters used in the predicting step in order to cause the predicted optical response to converge with the monitored response.

15. A method as recited in claim 12 wherein said probe beam is generated from a broadband source and said monitoring step is carried out as function of wavelength.

16. An apparatus for determining overlay error between two or more patterned layers of a sample, comprising,

a metrology target comprising a first diffraction grating built into a patterned layer A and a second diffraction grating built into a patterned layer B, where layers A and B are part of the sample under test and layers A and B are desired to be aligned with respect to each other, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the layers A and B;

an optical instrument that illuminates part or all of the metrology target and that measures properties of light that has interacted with the metrology target as a function of any one or more of polar angle of incidence, azimuthal angle of incidence, and polarization of the illumination and detection; and

a processor which estimates the offset of the grating pair from the measured properties.

17. The apparatus of claim 16 wherein the first and second diffraction gratings have different pitches.

18. The apparatus of claim 16 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

19. The apparatus of claim 16 wherein at least one other layer of material separates layers A and B at the metrology target.

20. The apparatus of claim 16 wherein the optical instrument measures properties of light that has interacted with the metrology target as a function of wavelength.

21. The apparatus of claim 16 wherein the processor has been programmed to iteratively (i) calculate an optical response for a set of sample parameters, including overlay misalignment, (ii) compare the measured properties with the calculated optical response, and (iii) change one or more sample parameters so as to minimize the difference between the measured properties and the calculated optical response,

wherein the calculation of an optical response is according to an optical model of the sample that accounts for the diffraction of electromagnetic waves by the pair of gratings of the metrology target and the interaction of the gratings with each other's diffracted field.

22. The apparatus of claim 21 wherein the processor has access to a pre-computed database from which at least a portion of the calculated optical response can be retrieved.

23. The apparatus of claim 22 wherein the calculation performed by the programmed processor involves interpolating the optical response from pre-computed entries in said database.

24. An apparatus for determining the overlay error comprising,

a metrology target comprising a first diffraction grating built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the layers A and B;

an ellipsometer that illuminates part or all of the metrology target and that measures properties of light that has interacted with the metrology target; and

a processor which estimates the offset of the grating pair from the pair's measured optical characteristics.

25. The method of claim 24 wherein first and second diffraction gratings have different pitches.

26. The apparatus of claim 24 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

27. The apparatus of claim 24 wherein at least one other layer of material separates layers A and B at the metrology target.

28. The apparatus of claim 24 wherein the ellipsometer measures properties of light that has interacted with the metrology target as a function of wavelength.

29. The apparatus of claim 24 wherein the processor has been programmed to iteratively (i) calculate an optical response for a set of sample parameters, including overlay misalignment, (ii) compare the measured properties with the calculated optical response, and (iii) change one or more sample parameters so as to minimize the difference between the measured properties and the calculated optical response,

wherein the calculation of an optical response is according to an optical model of the sample that accounts for the diffraction of electromagnetic waves by the pair of gratings of the metrology target and the interaction of the gratings with each other's diffracted field.

30. The apparatus of claim 29 wherein the processor has access to a pre-computed database from which at least a portion of the calculated optical response can be retrieved.

31. The apparatus of claim 30 wherein the calculation performed by the programmed processor involves interpolating the optical response from pre-computed entries in said database.